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# Efficiency of using dump trucks BELAZ-75180

**Yuliya Lagunova<sup>1,2,\*</sup>, Vladimir Bochkov<sup>2</sup> and Sergey Horoshavin<sup>1,2</sup>**

<sup>1</sup>Ural Federal University named after the first President of Russia BN. Yeltsin, 19, Mira St., Yekaterinburg, 620002, Russia

<sup>2</sup>Ural State Mining University, 30, Kuibyshev St., Yekaterinburg, 620144, Russia

\*yu.lagunova@mail.ru

**Abstract.** A comparative analysis of operational characteristics when using a different type of chassis of BELAZ-75180 mining dump trucks was performed. It is shown that the choice of the type and means of mining transport is determined by several factors, and, first of all, the characteristics of the cargo being transported, the distance of transportation, speed of flights, and the leverage for the given period. The power of vehicles and the performance of a mining dump truck depend on the scale of work (cargo turnover). The dependence of energy consumption during transport work on a quarry on the average size of pieces of rock is disclosed. The analysis of the dependence of the number of backup dump trucks on their number operating in a specific period is given. As a result of the analysis of operational characteristics, it was found that the chassis type of the BELAZ-75180 mining dump truck significantly affects its performance.

## 1. Introduction

The work of automobile transport in a quarry is characterized by a combination of harsh climatic, mining and technological and operating conditions, such as high and low ambient temperatures, dustiness of the atmosphere, great depth, an increase in the number of empty and zero runs, downtime associated with maintenance and repair of dump trucks [1-3].

The main limiting factors when using automobile transport in quarries are the transportation distance, the height of the rock mass and the slopes of the roads [4-5].

An indicator characterizing the laboriousness of carrying out transport work by mining dump trucks is the weighted average slope, the value of which allows you to consider horizontal, slightly inclined and steep sections of the route. Depth of development has the greatest impact on productivity and technical and economic indicators of open pit mining [1-13].

The share of transportation in the total cost of production is 50% or more. Therefore, reducing transportation costs is one of the important tasks of increasing the technical and economic indicators of an open development method. Vehicle performance is estimated either by the volume of transported rock mass (in m<sup>3</sup> or tons), or the value of cargo turnover (ton-kilometers) [1-13].

The efficiency of vehicles depends to a large extent on the complexity of the route, determined by slopes, curves, adjoining and crossing sections at the same level, blind turns, intersections with highways, level crossings, etc. It has been established that the performance of dump trucks in such sections decreases by 20-35% [1-13].

To determine the parameters of mining dump trucks being developed for the future and optimize their operational efficiency, it is necessary to know their performance and its dependence on



technological, environmental and climatic conditions and the characteristics of the mechanisms installed on them, and the type of chassis will play a significant role here.

## 2. The purpose and objectives of the study

The purpose of the study is to analyze the efficiency of the use of mining dump trucks using the example of a comparative analysis of the use of conditional chassis No. 8 and No. 16.

Research Objectives:

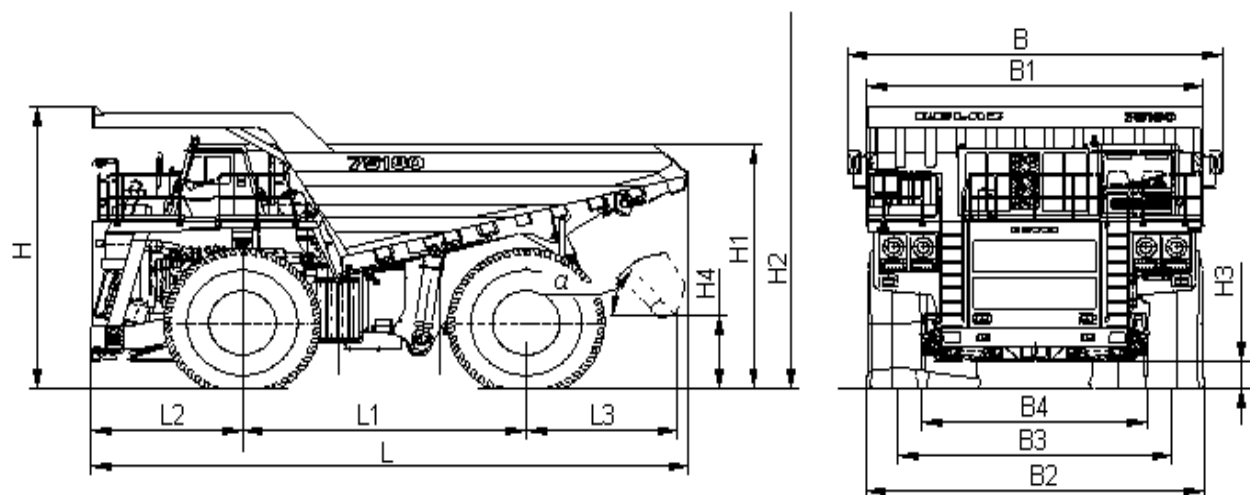
- analysis of operational performance of mining vehicles;
- compilation of a probabilistic model of the influence of various factors on the use of one or another type of chassis of BELAZ mining dump trucks;
- substantiation of the influence of the type of the chassis of the BELAZ-75180 mining dump truck on its performance.

## 3. The solution of research problems

The object of study is the chassis No. 8 and No. 16 of the BELAZ-75180 mining dump truck.

The subject of the study is the establishment of the effectiveness of the use of mining dump trucks for a period.

Research methods - analysis of the results of scientific research based on a probabilistic model of the influence of various factors on the use of one or another type of chassis of a BELAZ-75180 mining dump truck, a diagram of which is shown in Figure 1.



**Figure 1.** BELAZ-75180 mining dump truck.

Overall dimensions (without cargo): length  $L = 12.60$  m; width  $B = 7.75$  m; height  $H = 6.32$  m; wheelbase  $L1 = 5.80$  m; front overhang  $L2 = 3.40$  m; the distance from the lower point of the raised platform to the axis of the rear wheels  $L3 = 3.07$  m; platform width  $B1 = 6.85$  m; width on wheels  $B2 = 7.10$  m; front wheel track  $B3 = 5.60$  m; track of rear wheels  $B4 = 4.75$  m; loading height  $H1 = 5.60$  m; height with a raised platform  $H2 = 13.15$  m; ground clearance  $H3 = 0.85$  m; the height of the lower point of the raised platform  $H4 = 1.85$  m; maximum discharge angle  $\alpha = 46$  deg

Mining transport has several the following features that distinguish it from public transport [1-13]:

1. Loading and unloading points are constantly changing their position, following the front of mining, which requires periodic movement of transport communications and equipment (railways, roads, conveyors).
2. The cycle of discontinuous mining vehicles (railway, automobile, etc.) consists of loading, moving with cargo, unloading and returning empty.
3. Transportation from the quarry occurs, as a rule, on a large slope during the development of both

deep and upland deposits.

4. For the productive use of mining and transport equipment (excavators and rolling stock), mutual coordination of their parameters is necessary. The main requirements for Mining transport are: ensuring the specified cargo turnover; uninterrupted operation (exact adherence to the traffic schedule for cyclic vehicles and flow continuity for continuous vehicles); possibly less laborious work (due to the use of mechanization and automation of the main and auxiliary processes during transportation); traffic safety and work. One of the main provisions when choosing transportation schemes is the separation of overburden and mineral flows, which is advisable, for example, in conditions of large and medium production capacity of quarries (if mining and geological conditions allow), as it ensures the rhythmic and uninterrupted operation of the entire enterprise. The choice of the type and means of mining transport is determined by several factors and, first of all, the characteristics of the transported cargo, the distance of transportation, the scale of work and the pace of their development. The power of vehicles depends on the scale of work (cargo turnover), and the pace of mining determines the requirements for the operational reliability of mining vehicles.

The use of dump trucks in the transport system determines a significant variation in cargo flow parameters.

Analysis of the dynamic characteristics of the cargo flow indicates two of its modes: stationary and transitional (beginning and end of the shift and lunch break) indicates a significant non-uniformity during the shift. The coefficient of variation of freight traffic inequality by shift hours, as shown by previous studies [1–13], is 31%.

In addition, the complexity of the grades of the faces also predetermines fluctuations in freight traffic. Thus, the probabilistic distribution of overburden cargo flow over shifts is characterized by a coefficient of variation of  $\pm 18\text{--}19\%$ .

Thus, with a certain mathematical expectation of the average hourly value of the cargo flow, by which the throughput of the transshipment point is determined, the actual arrival of dump trucks for transshipment in hourly intervals varies significantly.

One of the main indicators characterizing the operation of dump trucks is the time ( $t$ ) of its operation during the studied period.

$$t_w = T_s - t_d \quad (1)$$

where  $T_s$  is the duration of the working part of the studied period of time (shift),  $r$ ;  $t_w$  - the duration of the dump truck, including standard downtime during the studied period of time in fractions of a unit from  $t_w$ ;  $t_d$  - the duration of excess downtime during the studied period of time in fractions of a unit from  $T_s$ .

The duration of the dump truck's operating time and the excess downtime depend on a number of reasons, one part of which is directly related to the dump truck itself (the level of professional skill and personal qualities of the driver, the technical condition of the dump truck, the design model of the chassis), and the other depends on reasons not related to the dump truck itself, but affecting the final results of its work (delays of the dump truck at the places of loading and unloading, road conditions, etc.).

This shows that the length of time the dump truck operates depends on a very large number of factors and is a random variable.

The probability of interpretations of the dump truck operating time, expressed in fractions of a unit of the duration of the working part of the shift, is the probability of dump truck failure.

Delivering the rock mass from the bottom to transshipment points or transporting overburden to dumps of rock, a group of  $n$  dump trucks engaged in this technological process combines the nature and purpose of the work performed in one system; the quantitative performance of each dump truck has a different effect than on one dump truck.

As a result of this, the quantitative indicators of the system's work can significantly differ from the planned ones, which were obtained by processing the initial data by commonly used calculation methods. The reason for this error lies in the fact that these methods approximately consider the whole variety of factors, their random nature and simultaneous influence on each other.

The usual ways to increase the quantitative indicators of the system are to improve the technical condition of dump trucks and the quality of roads, the intensification of loading and unloading, etc. In addition to these measures, it is possible to improve some quantitative indicators of the system due to the appropriate selection and combination of values of variable parameters.

Below we will try using the mathematical theory of reliability to consider the operation of such a system. The purpose of the review is to present this system as a probabilistic model and to determine the influence of the main parameters of the system on the results of its operation.

Due to the excess downtime of each dump truck for  $t_i$  time units (for example, shift parts in fractions of a unit from it), a system consisting of  $n$  dump trucks loses a certain part of its duration.

Loss of system performance is determined by the expression

$$P_{tot} = t_1 + t_2 + \dots + t_n = \sum_{i=1}^n t_i \quad (2)$$

where  $P_{tot}$  - the total downtime of all dump trucks systems, car shifts.

System performance lost as a result of downtime of dump trucks cannot be compensated by their increased performance in subsequent periods of time, i.e. failed elements (machine changes) are not returned to the system. This allows us to consider the system as unrecoverable [13].

In the process of manning the system, the number of dump trucks is determined by the expression

$$n = \frac{Q_{rm}}{r_p q_a} \quad (3)$$

where  $n$  - the number of dump trucks in the system;  $Q_{rm}$  - the amount of rock mass that must be transported by the system during the shift,  $m^3$ ;  $r_p$  - the average number of flights made by one dump truck during a shift;  $q_a$  - carrying capacity of one dump truck, tons.

For the system to cope with the planned volume of traffic during the entire studied period, it is necessary to constantly participate in the work of all dump trucks. The average number of trips made by one dump truck during a shift, which is obtained from experimental data for a sufficiently long period of time, considers all the factors that determine it, including excessive downtime. In case of excess downtime of one or several dump trucks, they will work less than is necessary for the normal operation of the system, based on expression (3).

A part of the studied time period during which a system with a series connection of elements will regularly perform its functions is interpreted as the probability of a system uptime and is determined from the expression

$$R(t) = P^n \quad (4)$$

where  $R(t)$  - the probability of system failure;  $P$  - the probability of failure of one dump truck.

Often the number of dump trucks taking part in the technological process is taken large by the number of dump trucks that fail in the process, that is, a reserve of dump trucks is entered into the system. This allows us to consider it as a system with a loaded reserve of [2]. The fundamental difference between this system is that the failure of one or more dump trucks does not lead to the failure of the entire connection until the number of failed elements exceeds the reserve that was deliberately assigned to the system.

The probability of failure-free operation of such a system is

$$P(t) = \sum_{i=n}^n \frac{n_i!}{(n_i-i)!i!} P^i (1-P)^{n_1-i} \quad (5)$$

where  $P$  - the probability of failure of one element, represented by  $t_w$ .

The probability of failure of a dump truck of such a system, consisting of their number  $n$  or  $n_1$ , is determined below.

Assuming that downtimes are sudden, the law of the distribution of time of their occurrence is exponential and the probability of failure-free operation is determined by the expression

$$P = e^{\lambda t} \quad (6)$$

where  $\lambda$  - the failure rate, expressed by the number of failures per unit time.

The failure rate is determined

$$\lambda = \frac{P_{tot}}{T} \quad (7)$$

where  $P_{tot}$  - the total number of failures during the shift, determined by the expression (2);  $T$  - total test time

$$T = \bar{N}_{av} t \quad (8)$$

$\bar{N}_{av}$  - the average number of fail-safe elements;  $t$  - the duration of the test.

$$\bar{N}_{av} = \frac{\bar{N}_{in} + \bar{N}_{fin}}{2} \quad (9)$$

$\bar{N}_{in}$  - the initial number of items to be performed by the work;  $\bar{N}_{fin}$  - a finite number of elements that did not fail by the end of the test interval.

When connecting elements in series, we have

$$\bar{N}_{av} = \frac{2\bar{n} - P_{tot}}{2} \quad (10)$$

With a parallel connection of calculation elements, expression (10) has the form

$$\bar{N}_{av} = \frac{2\bar{n} + P_{tot}}{2} \quad (11)$$

With serial ( $P_1$ ) and parallel ( $P_2$ ) connection

$$P_1 = t \frac{-2P_{tot}}{2\bar{n} - P_{tot}} \quad (12)$$

$$P_2 = t \frac{-2P_{tot}}{2\bar{n} + P_{tot}} \quad (13)$$

Expression (7) is valid only under the following conditions:

- failed elements during the test are not replaced or repaired;
- the probability of failure-free operation of each element is subject to an exponential law;
- the time interval is so small that a linear approximation of the exponent on this interval is justified.

In a specific case, these assumptions are valid for the following reasons:

- failed elements in the process are not replaced, this allowed us to consider the system as unrecoverable;

- the probability of failure-free operation of each element obeys an exponential law;
- in the considered period, a linear approximation of the exponent will not give noticeable errors.

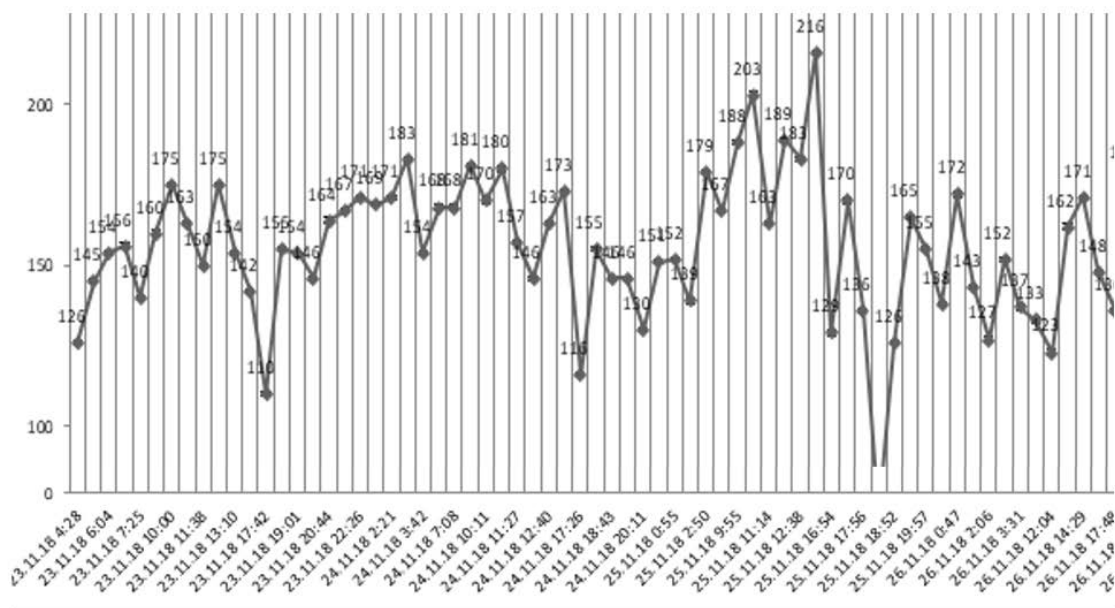
There are frequent cases when a certain number of dump trucks starts working after the start of the shift. If we consider the number of dump trucks that started working in a timely manner as the initial number of elements (excluding arriving later dump trucks), then the final number of elements may turn out to be larger than the initial one. Such an assessment of the initial and final number of elements of the compound excludes the possibility of using expressions (7), (10), (11), since the prerequisite is the absence of replacement. For the amount transported by dump trucks per shift, it does not matter when a certain number of dump trucks was lost (at the beginning, middle or end of the shift), but only the number of failures is important.

Therefore, in the expressions (10) and (11), the initial number of elements should indicate their maximum number that took part in the system during the entire considered time period, regardless of when and how much time this maximum number was in the system elements. In this case, the loss of elements in the system is considered by expression (2), and the final number of elements is their minimum number, which participated in the system for the entire studied period

The research results are based on the accumulated statistics on the operation of two types of chassis and are shown in tables 1 and 2 and in the diagrams in figures 2 and 3.

**Table 1.** Fragment of statistical data BELAZ-75180 (chassis 8)

Dump truck	Round	Weight (loading)	Weight (unloading)	Way (empty)	Way (loaded)	Loading time	Travel time	Path (shoulder)	Loading time	Trip time
8	2	126	132	4659	741	128	741	5400	0:02:08	869
8	3	145	153	665	4167	170	586	4832	0:02:50	756
8	4	154	173	3197	2716	198	454	5913	0:03:18	652
8	5	156	163	2730	2715	194	714	5445	0:03:14	908
8	6	140	154	2724	2709	188	405	5433	0:03:08	593
8	7	160	168	3132	1566	241	517	4698	0:04:01	758
8	8	175	184	1604	1584	246	440	3188	0:04:06	686
8	9	163	174	1621	1582	241	468	3203	0:04:01	709
8	10	150	160	14844	793	592	395	15637	0:09:52	987
8	11	175	188	800	5582	460	977	6382	0:07:40	1437
8	12	154	172	5506	5527	399	785	11033	0:06:39	1184

**Figure 2.** BELAZ-75180 statistical data fragment diagram (chassis 8).

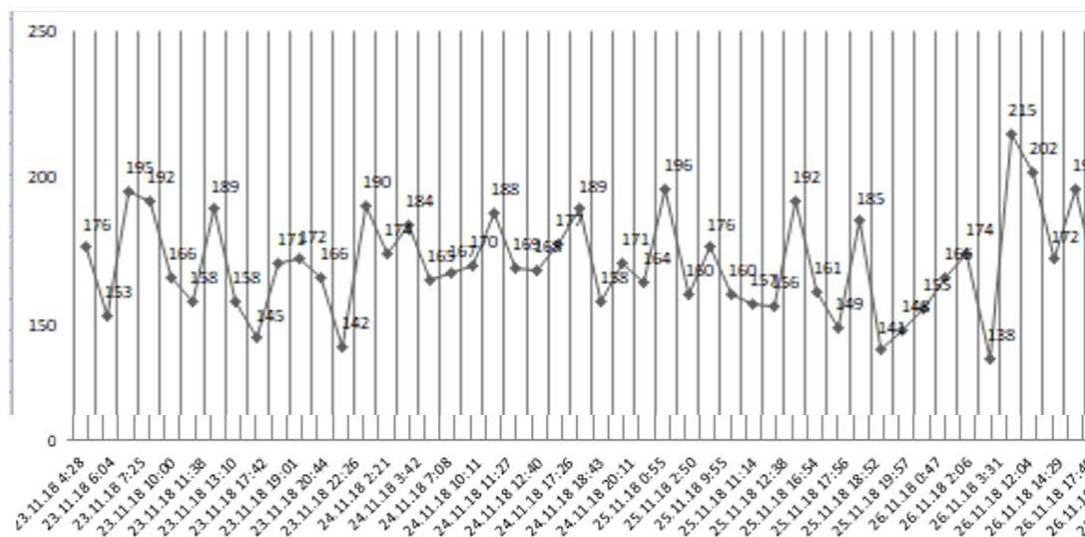
Average loading time 3.58 min; average flight speed 25.64; middle shoulder 8629; relative mileage of a loaded dump truck 0.484; total loading time 253626; operating time of the dump truck 1291094; the performance of the dump truck is 1303645.81.

Average loading time 3.2 min; average flight speed 26.17; middle shoulder 8076; relative mileage of a loaded dump truck 0.492; total loading time 171705; operating time of the dump truck 952240; dump truck performance 1042921.63.

As a result of the evaluation of statistical data, it was found that the average operating time of chassis No. 8 is 26.29% longer, the total loading time is 32.3% longer and the total productivity is 25% higher.

**Table 2.** Fragment of statistical data BELAZ-75180 (chassis 16).

Dump truck	Round	Weight (loading)	Weight (unloading)	Way (empty)	Way (loaded)	Loading time	Travel time	Path (shoulder)	Loading time	Trip time
16	2	153	159	5118	4949	156	897	10067	0:02:36	1053
16	3	195	205	5137	5065	268	983	10202	0:04:28	1251
16	4	192	204	5229	5185	169	1304	10414	0:02:49	1473
16	5	166	185	5160	5113	203	1987	10273	0:03:23	2190
16	6	158	171	5082	4350	137	539	9432	0:02:17	676
16	7	189	201	4363	4459	159	2273	8822	0:02:39	2432
16	8	158	170	4612	4580	190	1015	9192	0:03:10	1205
16	9	145	156	4790	4389	156	600	9179	0:02:36	756
16	10	171	182	4668	5191	178	1297	9859	0:02:58	1475
16	11	172	185	5218	5127	170	882	10345	0:02:50	1052
16	12	166	172	5649	5177	171	636	10826	0:02:51	807

**Figure 3.** BELAZ-75180 statistical data fragment diagram (chassis 16).

Thus, the above methodology for solving problems related to the analysis of the efficiency of using BELAZ mining dump trucks can be implemented by the following procedure:

1. The probability of failure-free operation of each of the dump trucks is determined. If they are known, but not equal, then the general excess downtimes of the system (2) are determined, and then the average probability of failure-free operation of each of the dump trucks according to expressions (12) and (13).

2. The probability is determined that at least  $n$  of the total number of machine-shift calculation elements will work in the system.

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